From the Author
to His Friend
John Bransby Cooper

ON THE PATHOLOGY AND TREATMENT OF FRACTURE OF THE NECK OF THE THIGH BONE.

BY BRANSBY B. COOPER, F.R.S.

In the remarks on this subject I shall chiefly confine myself to those fractures which take place within the capsular ligament, for these are the accidents which are least affected by the methods of treatment commonly adopted for their alleviation and cure. The modes of treatment in use are of two kinds, and differ widely in their nature and objects. These differences in practice arise from corresponding differences in opinion, respecting the nature of the injury and its consequences; and, as it is highly necessary to appreciate these distinctions, I will, as briefly as possible, describe the two doctrines to which I allude. There are many surgeons who believe and teach, that fractures within the capsular ligaments unite by the same natural processes of reparation as fractures of the other parts of the osseous system, necessarily, one would suppose, inferring, that the structure of each is identical. It follows, of course, that those who hold these opinions employ mechanical means in order to obtain that union between the broken extremities, which they deem to be equally desirable and obtainable as in common cases of fracture.

The second doctrine is that which the late Sir Astley Cooper has the just merit of having first promulgated, and which diametrically differs from that already described. He maintained that, in fact, nature is opposed to the osseous reunion of such an injury, and that the attempt is never made after the fractured portions have been once separated; but only in such cases as those, in which the periosteum of the neck has not been torn through, so that the two portions remain in close apposition, and that then they only unite by a very slow process, similar to that which occurs in the reparation

of fracture of the bones of the head. Under these circumstances, however, a mystery is involved how the surgeon is to detect the injury in the absence of all the diagnostic marks, of shortening, eversion, and crepitus; and even should he suspect it, nothing further could be done than to recommend perfect rest in the recumbent posture. The abstract view of the treatment of fractures cannot, in itself, lead to the true pathology of this accident: the physiology of the bony fabric must be first perfectly understood for the reparation of this accident to be justly appreciated. It is not because the bones all possess the physical qualities of hardness, and the chemical admixture of animal and earthy matters, that they are all to be considered as subjected alike to the same laws, either in their original growth, or mode of reparation after injury; for it will be found that they differ as much in their vital constitution as they do in their geometrical form, to fit them for, and to maintain, the variety of purposes they are destined to perform in the animal economy. Did the same laws regulate the union of the articular extremity of a bone which completes the restoration of a broken shaft, a joint would necessarily be destroyed whenever one of the bones entering into its composition was the subject of fracture, as the formation of the provisional callus would necessarily prevent every motion between the bones, and lead to the destruction of the various structures of the articulation. From this it follows, of course, that union, being regarded as a result not to be obtained in cases of fracture of the neck of the thigh bone within the capsular ligament, no means are employed having such an object; but that the attention of the surgeon is directed to other sources for administering to the welfare of the patient, consistent with the advanced period of life at which the accident so constantly occurs.

The very brief exposition thus given of the two doctrines, I trust, sufficiently points out their essentially different natures and indications in practice, and, perhaps, may serve (remembering the high authorities by which each has severally been supported) to awaken the interest of those who have been simply followers of that doctrine which they may happen to have been taught in their schools, and lead them

to inquire into the respective merits of both the one and the other. Moreover, considering the frequency of the accident, it becomes the duty of the practical man to make himself acquainted with the discussions on the subject, in order that he may be able to judge more correctly what course to pursue when called upon to treat this peculiar accident. This he is the more bound to do, because even those who maintain the possibility of union admit, that with all their mechanical contrivances, it is rarely indeed, that they succeed in effecting the desired union.

I shall not consider the diagnostic marks of the accident, because, as these are to be found fully detailed in the writings of our best surgical authors, I shall presume the reader to be fully acquainted with them. I shall therefore enter at once into the more immediate object of this essay, and, for perspicuity's sake, adopt the following plan:—

In the first instance I shall discuss the fact of the failure (in almost all cases) of inducing union of fractured neck of the thigh bone, even after the most assiduous application of the most complicated apparatus, and shall attempt to point out what are the true causes of such failures, as far as refers to the mechanical difficulties.

Secondly, I shall examine into certain natural conditions of the neck of the thigh bone, in old people especially, which not only seem to preclude the possibility of bony union, but even to indicate certain provisions for the prevention of such union, as if to avoid the ill consequences which, at this part of the body, would necessarily arise from the usual mode of ossific reparation.

Thirdly, I shall conclude by briefly describing that treatment which is attended with the most beneficial results in these cases.

First, as to the alleged mechanical causes of failure. These are usually described as referrible to the extreme difficulty in producing perfect co-aptation of the fractured extremities of the bone, as well as in maintaining a sufficient degree of pressure upon them. The distention of the synovial membrane by the inordinate secretion of synovia is also alleged as offering a difficulty in producing a contiguity of the two portions. And, lastly, the isolated condition

of that portion of the neck attached to the head of the bone from the circulating system is supposed to offer a further obstacle to reunion.

The principal causes which prevent mechanical means being efficient in producing co-aptation in these cases, seem to be evidently traceable to the peculiar circumstances under which the neck of the thigh bone is naturally placed, the variety of its motions, its length, the peculiar angle at which it is attached to the shaft of the bone, the direction in which the weight of the body is transmitted to it, together with the insertion of its muscles into the one fractured portion only;—all circumstances which must tend to render continued apposition of the fractured ends extremely difficult; and hence has arisen the various contrivances for producing this supposed desirable effect, such as Mr. Amesbury's splints, Earle's bed, and such like useless apparatus for these cases;—useless, because they are inapplicable to the purpose intended; and highly injurious to the patient, who, at the period of life at which this accident occurs, is ill capable of supporting protracted confinement in bed, and the infliction of continued extension and pressure of the limb. As to the distention of the synovial capsule from the inordinate secretion of synovia, I cannot see how that should tend in any way to prevent the approximation of the fractured ends of the bone. That there are obstacles, and depending on physical conditions, none can doubt; but could these by any means be overcome, there still remain other causes which prevent bony union. These are not, however, mechanical, but having their origin in certain vital conditions, and which are connected even with the very occurrence of the accident. It is to these we must look for the real, the insuperable impediments to ossific union, and we shall learn by the investigation the best means to be adopted for the treatment of the patient.

Among the chief vital causes preventing bony union are,

First, The low condition of the reparative powers, generally consequent on the advanced period of life at which this accident occurs.

Secondly, The remarkable changes peculiar to the hip joint from age, especially to the portion of the femur implicated in this injury.

Thirdly, The peculiarities of original structure.

These vital causes are powerful in their operation inversely to the order in which I have named them, the last being the strongest. I have adopted, however, this succession, because, in considering them severally, should the objections which arise out of the consideration of the first and second not be thought to be in themselves conclusive, the additional weight which they receive from the third, seems fully to prove, that, taken together, these vital conditions must counteract any attempt at producing union. They are, moreover, when pathologically considering the subject, naturally presented to the mind in this order.

With respect to the influence of age as a cause of fracture of the neck of the thigh bone within the capsular ligament, I cannot possibly bring that subject before my readers in a stronger point of view than by quoting the words of the late Sir Astley Cooper, who says, "The age at which fractures of the neck of the thigh bone within the capsular ligament generally occur is a most important consideration; and as it is one on which the practice to be pursued by the surgeon very much depends, I shall take the liberty of making the following statement:—I have been forty years at St. Thomas's and Guy's Hospitals, and for thirty years have had more than my share, and much more than I merited, of the practice of London. We have eight hundred and fifty patients in the two Hospitals, and I believe that in these two Institutions eight cases of fracture of the upper part of the thigh bone occur in each year; but in order to avoid exceeding the average number I will consider them only as five per annum. Thirty-nine multiplied by five produce one hundred and ninety-five: add to these one case only each year, in my private practice of thirty years, they will collectively amount to two hundred and twenty-five cases. Now in that time I have only known two cases of fracture of the neck of the thigh bone within the capsular ligament *occur under fifty years of age*: one was in a patient, aged thirty-eight, who had aneurism of the iliac artery, and the other has been kindly shewn to me by that excellent anatomist Mr. Herbert Mayo, &c.

"That this state of bone in old age tends much to the production of fracture is shewn by the slight causes which often occasion them, &c."

The general condition of the whole human frame at this period of life undergoes changes which are sufficiently obvious to common observation: the body, in fact, wastes, and every action indicates diminished vital power: it is supposed that there is a general tendency to absorption rather than to supply. But perhaps the truth is, that the depositions which occur are of a different character, attributable probably to the diminished power of the assimilative functions. The osseous system, in common with every other tissue in the body, undergoes this change inseparable from age, and the constituents of the bones no longer maintain those proportions essential to their integrity; and although, as is sometimes found, that even in advanced age the reparative powers retain their energy, these are but exceptions to the general rule, and such persons, I may justly say, are not prone to the accident in question; for it is the altered condition of the bones which equally renders it obnoxious to fracture, and incapable of reparation.

The changes which take place in the neck of the thigh bone in old age are hardly to be considered peculiar to this part, for it is more or less going on in every articular extremity of a bone, and the altered physical condition is marked by the changes which take place in the motions of the joints at advanced periods of life; although the neck of the thigh bone indicates these changes more than in any other bone, in consequence of the great weight and violent exertions to which it is exposed. Let any one examine the upper extremity of a healthy adult femur, and the neck will be found branching from the shaft of the bone at an angle of 45°; but if an old bone be the object of observation, the head will be found depressed upon a level with the trochanter major, so that the neck forms a right angle with the shaft, and is infinitely shorter than it had been in youth, indicating an altered state of nutrition depending on the relative condition of epiphyses in old age and youth. Matters of the greatest importance arise in reflecting on these natural alterations in structure. May it not be considered to exhibit an adaptation in the state of this part to the general altered condition of the rest of the frame, and thus lead to the conclusion of the uselessness, if not of the impropriety, of attempting to produce bony union?

All the structures entering into the composition of a joint are incompetent to the formation of earthy matter, with the exception of the articular extremities of the bone; and they, indeed, are so differently organized from the other parts of the bone to which they belong, that it is twenty years before they are consolidated; from which period they maintain themselves by a supply of blood, seemingly as much for the purpose of nourishing the articular cartilage as the bone itself; but so soon as those changes take place, concomitant with old age, this source of nutrition becomes diminished, and a great physical and vital change is at once established, and more especially in the neck of the thigh bone, from conditions already described. This bone now attenuates, sinks, and is liable to give way from the application of the slightest force: hence it is not co-aptation, pressure, or the application of any surgical means, which can enable the part to restore itself. Amongst other peculiarities in the structure of those portions of the osseous system surrounded by synovial membranes, and covered at their extremities by permanent cartilage, may be enumerated the absence of those tissues which are connected with the bones in every other situation, and which perform so important an office in their reparation when fractured. Nor can I better point out the natural results arising from the want of such tissues, than by briefly describing the reparation of fractures of the bones generally. The effects of a simple fracture of a bone are, first, effusion of blood, its coagulation, absorption of its serum and red particles, solidity, and perhaps the organization of its fibrin, which I think I have seen in the medullary clot. Inflammation of the surrounding tissues is next set up, producing an effusion of coagulable lymph, and which soon hardens into a cartilaginous density. During this period the whole tumefaction presents an homogeneous mass in appearance, completely surrounding the fractured extremities of the injured bone, and by its increase of density presses the broken portions together. Where the bones come in contact their periosteum is absorbed, and then it is that the permanent process of reunion commences, all hitherto having been merely temporary, or a provisional action. It is now that the true osseous consolidation commences; and as it advances the pro-

visional bone is absorbed, and the whole callus is regendered into the original structures from which it had been effused, and not for several months is the fractured bone permanently united. As none of these preparatory actions can occur in fractures of the neck of the thigh bone; and as it is next to an impossibility to keep the fractured portions in apposition by any mechanical means; and further, as the subject of this accident is always so far advanced in life as to be unable to support a protracted confinement in the recumbent posture for the necessary length of time for bony union, supposing nature attempted such an action, I cannot understand how any pathologist can expect ossific union in these cases. What had been the result, if such union were admitted, that the provisional callus itself would have filled up the acetabulum, and in every way would have so completely interfered with the structure of the joint, as, in itself, to have proved destructive to the performance of every natural function of the limb? My object has been throughout to maintain that it is ordained by nature that fracture of the neck of the thigh bone within the capsular ligament is not to unite by ossific deposition; and what stronger proof of this fact can there be, than that, in the process of reparation of such fractures as occur external to, as well as within, the joint, the bony union takes place up to the very edge of the attachment of the synovial membrane, and no further? for beyond that point there are no structures capable of producing a provisional callus: so that the first periods or epochs of ossification never take place, and the permanent growth of the fractured portions together, by bone, cannot occur: first, for want of adaptation; and secondly, because the vessels of the neck are not intended to appropriate their blood to the deposition of bone. Even the necks of old femora which have not been broken, and therefore their natural organization remaining undisturbed, will be found, by analysis, to have lost their power of generating phosphate of lime, the deficiency of which, it is, that renders them so susceptible of fracture from the slightest violence. This change during the latter periods of life probably occurs in all the epiphyses. To establish the different condition of the epiphyses from the rest of the osseous system, I will

describe what I have found to be the organization of the epiphyses by my own injections, as well as by those of Mr. Toynbee, who, in the kindest manner, gave me access to his beautiful preparations, which, although made with an object quite different to my own, tend exactly to illustrate the views which had induced me to instigate the inquiry; my idea being that an epiphysis was an apparatus expressly designed for the formation of articular cartilage; Mr. Toynbee's object being to ascertain whether or not articular cartilage, among other particular tissues—as cornea, crystalline lens, epidermis, &c.—were non-vascular. In the examination of a fœtal thigh bone at an early period no difference can be observed between the epiphyseal and articular cartilage; but at the transverse centre, vessels may be seen to enter which are distributed from the arteries of the surrounding fibrous tissues, making their course towards the internal centre, where ossification commences, and prior to which period red blood is not circulated in them.

The osseal attached surface of the epiphysis receives no blood-vessels from the shaft of the femur, although canals run into it which are frequently found injected from the arteries of the bone; but this occurs wholly from extravasation, for the injection will invariably wash out; shewing that it is not enclosed in a vessel, but at the same time proving that some nutrient apparatus is existing between them, and exerting an influence, perhaps, through every period of life, but especially previous to the ossification of the epiphysis. The articular surface of the epiphysis is in a like manner separated from the articular cartilage, and its blood-vessels terminate in a similar manner as those at the epiphyseal extremity of the shaft of the femur; and through canals in the articular cartilage a kind of communication exists between these vessels and those which supply the synovial membrane, but not by anastomosis as arteries usually unite. There appear, therefore, to be three sources by which the epiphyses are nourished, although hardly to be said actually to be supplied with blood-vessels. At the osseous extremity, nutrition is derived from the capillary vessels of the extremity of the shaft of the bone: the fringed and distinct arrangement of these capillaries form the apparatus by

which the nutrient matter of the blood is appropriated to the cartilage. The articular extremity of the epiphysis is in a similar manner nourished by the synovial capillary arrangement through the articular cartilage itself, while the central part of the epiphysis is supplied by direct vessels from the surrounding fibrous tissues.

May it not happen, therefore, that the differences which exist between articular and epiphyseal cartilage depend upon the synovial nutrient apparatus, which seems to produce that permanent condition which the articular cartilage inherits, while that of the epiphyses is only temporary? Such an opinion seems somewhat corroborated by the comparison between the epiphyses of joints and those of apophyses. In the latter we find they become rapidly converted into bone, and almost simultaneously over their whole surface, not leaving themselves tipped with a surface of cartilage, because they do not at any part derive nourishment from synovial membrane.

If such may be considered as the just pathological view of this accident, it may be fairly maintained, as I have already observed, that nature has ordained that these fractures are not to be united by bone: it is the result of organization which leads to the ligamentous union, and it is not the application of the most complicated mechanical contrivance which can lead to ossification. The treatment, therefore, of these accidents is to be regulated and modified by the consideration of the age of the patient; and, in my opinion, under the conviction of the uselessness of any attempt to produce bony deposition. The advanced age at which the accident so generally occurs precludes the propriety of the application of any apparatus, which, even if it could lead to union, would necessarily confine the patient for two or three months to bed, and for the same period subject him to a violent extension of the limb, which could but be highly injurious to the health of the individual, and would most assuredly prove abortive.

The following experiments were made with a view to ascertain whether any change, or, if any, what change, took place in the composition of the neck of the thigh bone in old age, which might prove sufficient to account for its tendency

to bend and to break at this period of life. The specimens of bone were selected with care, and portions being sawn off, were weighed, and then burnt for a sufficient time in a muffle to destroy the whole of the animal matter, after which they were again weighed, and the result recorded. The quantity of bone burnt in each instance varied from 150 to 300 grains.

The relative proportions of the phosphate and carbonate of lime were ascertained in a sufficient number of instances to prove that no perceptible difference worthy of remark occurred so as to mark, or even lead to the supposition that any change in the earthy constituents induced the physical alteration in the bone.

The following Tables present a view of the results obtained, and seem to account in a satisfactory manner both for the bending and easy fracture of the neck of the femur at advanced periods of life, which hitherto has been but little understood, as the preponderance of earthy matter had been always conjectured.

I.

Ex.	Bone earth.	Bone earth.
1.	100 grs. of fractured neck of unburied thigh-bone of person aged 68 yielded . . . . . 16·2	100 grs. of shaft of same bone yielded, 53·6
2.	100 grs. of fractured neck of femur extending external to capsular ligament of person aged 84 yielded . . . . . 24·3	100 grs. of ditto . . . . . 47·7
3.	100 grs. of another fractured neck yielded . . . . . 23·1	
4.	100 grs. of ditto . . . . . 24·1	100 grs. of ditto 49
5.	100 grs. of ditto 32	
	Average amount of bone earth . . 23·9	Average amount of bone earth . . 50·1

II.

Ex.	Bone earth.	Bone earth.
1.	100 grs. of neck of old bone unburied yielded 32	
2.	100 grs. of ditto . . . . . 30·5	100 grs. of shaft of same bone yielded, 49·4
3.	100 grs. of ditto 38	100 grs. of ditto . . . . . 61·6
	Average amount of bone earth . . 33·5	Average amount of bone earth . . 55·5

III.

Ex.		Bone earth.		Bone earth.
1.	100 grs. of neck of unburied bone of middle-aged person yielded,	40·5		
2.	100 grs. of ditto	56·8		
3.	100 grs. of ditto	52·6		
4.	100 grs. of ditto	45·2	100 grs. of shaft of same bone yielded,	56
5.	100 grs. of ditto	55·6	100 grs. of ditto	57·5
Average amount of bone earth . .		50·1	Average amount of bone earth . .	56·7

IV.

Ex.		Bone earth.		Bone earth.
1.	100 grs. of neck of old bone very dry yielded	59·2	100 grs. of shaft of same bone yielded,	62·1
2.	100 grs. of another yielded . .	60·6	100 grs. of ditto	63·4
3.	100 grs. of neck of old bone exhumed yielded	61·5	100 grs. of ditto	63·1
4.	100 grs. of another yielded . .	64·5	100 grs. of ditto	71
Average amount of bone earth . .		61·4	Average amonnt of bone earth . .	64·9

On inspecting the general average of these analyses, it will be seen that a remarkable deficiency of bone earth occurs in the neck of the femur in old age, whether it has been the subject of fracture or not: to illustrate this the more forcibly, let us inspect the above average in a tabular form.

AVERAGE.

I.	Fractured neck of femur yielded per cent of bone earth,	23·9	
	Shafts of same bones		50·1
II.	Unfractured neck of old bone not buried . . .	33·5	
	Shafts of same bone		55·5
III.	Unfractured neck of unburied bone of middle-aged person,	50·1	
	Shaft of same bone		56·7
IV.	Unfractured neck of old bones very dry or exhumed .	61·4	
	Shafts of same bones		64·9

To these may be added the results obtained from an anchylosed knee and a malignant tumor of the humerus, both quite dry. These analyses were instituted with the view of discovering the differences which occur in the composition of bones under the deteriorating influence of age, the reparative action of inflamed epiphyses, and the deposition of bone excited by a malignant action.

	ANCHYLOSED KNEE.		SHAFTS OF FEMUR AND TIBIA.	
Ex.		Bone earth.		Bone earth.
1.	100 gr. of joint of knee yielded .	44	100 gr. yielded	58·7
2.	100 gr. of tumor of humerus, do.	55	100 gr. of shaft of humerus,	62·2

From this it appears, that although the neck of middle-aged bone contains 50 per cent of bone earth, yet the recent neck of the old bone contains only 31 per cent; whereas the difference between the shafts is by no means so great, being 56 for middle-aged bone and 53 for old bone. In all cases, however, the shafts contain more bone earth than the neck.

Aware that these results differ entirely from the received opinion that the liability to fracture in old age arises from an excess of bone earth, I have not hastily arrived at an opposite conclusion; nor should I have trusted to actual experiment as the basis upon which to found an argument militating so strongly against an established aphorism; but reflecting on the mode in which the reparation of bone takes place in ordinary cases of fracture, it appeared to me little short of ridiculous to expect, in old age, an excess of bony matter, in a part which is so imperfectly vitalized, and which indeed, in common with all the epiphyses, is so many years consolidating into bone. In common fractures we find that animal matter is abundantly secreted within a few hours of the accident, whereas many days elapse before the formation of bone is even attempted; thus proving that a greater effort is necessary on the part of nature to accomplish the production of bone, than is required in the reparation of any of the softer structures. When, therefore, the powers of the constitution are gradually diminished by age, it seems but reasonable to expect that a certain state of the system must ultimately arise, in which bone earth is liable to be deposited in the more organized and vascular parts of the body; and hence, consequently, arises a diminution of the solid constituents of the bones, and especially in those which possess the least degree of vitality. The epiphyses are the first parts of the osseous system which become deteriorated from the want of earthy deposit, and the deficiency is made up by the deposition of cartilage, gelatine, and other substances more easily secreted than bone; whilst the tendency, at this period of life, occurs to the secretion of bone in the more highly-organized structures, as in the aorta, lungs, prostate gland, and kidneys, and not unfrequently giving rise to ossifications, or the formation of phosphatic calculi in the bladder or prostate gland. In support of this opinion we find that the com-

plaints alluded to for the most part occur at that period of life in which we are led to expect a want of power in the imperfectly-vitalized structures of the body; and these experiments may serve to convince us that we ought not to expect bony union in such situations, and that this becomes all but impossible after the middle period of life, as there ensues then a disposition rather to diminish than increase the due proportion of solid matter, and most especially in the articular extremities of the bones.

In order to prove, if possible, if I were right in my conjecture that all epiphyses, at every period of life, contained less earthy matter than their corresponding shafts, I instituted the following analyses:

Ex.	EPIPHYSES. Bone earth.	CORRESPONDING SHAFTS. Bone earth.
1.	100 grs. of head and neck of adult femur unburied yielded, 46·4	100 grs. of shaft . . . . . 60·8
2.	100 grs. of condyle of dry femur . . . . . 56·8	100 ditto . . . . . 61·73
3.	100 grs. of condyles of healthy unburied humerus . . . 46·29	100 ditto . . . . . 75·1
4.	100 grs. of ditto, dry . . . 62·63	100 ditto . . . . . 64·1
5.	100 grs. of head of young humerus dry . . . . . 24·44 100 grs. of condyles of ditto, 25	100 ditto . . . . . 57·5
6.	100 grs. of head of radius . 49·05	100 ditto . . . . . 61·38
7.	100 grs. of olecranon of ulna unburied . . . . . 48·9 100 grs. of carpal extremity of ditto . . . . . 42·81	100 ditto . . . . . 58·9

And the results, I think, may be considered as corroborative of the opinion I had formed.